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TESTS OF TUBULAR CHROMEL-ALUMEL THERMOCOUPLES

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NATIONAL BUREAU OF STANDARDS

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WRIGHT AIR DEVELOPMENT CENTER

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Power Plant Laboratory
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Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

FOREWORD

This report was prepared by the National Bureau of Standards, Washington, D. C., under USAF Contract No. (33,038)51-4063. The contract was initiated under the research and development project identified by Expenditure Order No. 540-20, and it was administered under the direction of the Power Plant Laboratory of Wright Air Development Center. Lt. D. M. Perkins is acting as project engineer.

ABSTRACT

This report presents the results of response rate and recovery factor tests of two experimental Chromel-Alumel thermocouples. The thermoelements are tubular in form and the sensing junction made by butt-welding the elements.

PUBLICATION REVIEW

The publication of this report does not constitute approval by the Air Force of the findings or the conclusions contained herein. It is published primarily for the exchange and stimulation of ideas.

FOR THE COMMANDING GENERAL:

for Norman C. Appold
Colonel, USAF
Chief, Power Plant Laboratory
Aeronautics Division

INTRODUCTION

This report presents the results obtained on the test of two tubular Chromel-Alumel thermocouples designed and constructed by Armour Research Foundation under AMC Contract AF 33(038)-17637. The tests to which the thermocouples were subjected include: (1) Determination of rates of response; and (2) Determination of recovery factor.

DESCRIPTION OF TEST THERMOCOUPLES

Figure 1 shows two views of the tubular Chromel-Alumel thermocouple. The junction is formed by butt-welding 0.005" strips of Chromel and Alumel. The welded strips are then trimmed and rolled into a tube 0.060" o.d. with the sensing junction located at the midpoint of the length of the tube. The tubular thermocouple is welded to No. 10 gage Chromel and Alumel lead wires and the leads are supported in a two-hole porcelain insulator as shown in figure 1.

RESPONSE RATE TESTS

A thermocouple suitable for the control of jet engines should respond rapidly to sudden changes in gas temperature because the temperature of the products of combustion changes almost instantaneously with the air or fuel rate and because the engine normally operates close to the maximum safe temperature for some of its parts.

When the temperature of the medium in which a thermocouple is immersed is increased instantaneously from T_1 to T_2, the increase, ΔT, in the temperature of the junction with time t thereafter is given by the equation:

$$\Delta T = (T_2 - T_1)(1 - e^{-t/\tau})$$

in which e is the base of Naperian logarithms and τ is a constant. If t is in seconds, the constant τ is the time in seconds required for the junction to undergo 63.2% of the change in temperature, $(T_2 - T_1)$, and is commonly referred to as the characteristic time of the junction. Actually it is not a characteristic of the junction alone, but of the junction and the system in which it is immersed, so that the gas flow rate must be specified simultaneously with the characteristic time.

The apparatus and experimental techniques employed in studying response rates and the method of obtaining the characteristic times of temperature probes are described in detail in AF Technical Report No. 6455, February 1951, and will not be repeated here.

The response rates of the tubular Chromel-Alumel thermocouples were determined at three flow rates, namely 2, 4, and 6 lbs/ft^2 sec. Each of the units, designated as No. 1 and No. 2, were tested at three orientations with respect to the gas stream: Position No. 1 - the sensing element directly upstream from the support; Position No. 2 - the sensing element and the support in the same plane at right angles to the direction of gas flow; and Position No. 3 - the sensing element directly downstream from the support. A summary of the observed values of characteristic time is given in table 1.

RECOVERY FACTOR TESTS

The effectiveness of a thermocouple for indicating the total temperature of a high-velocity gas stream is expressed by its recovery factor, r, defined as:

$$r = (T_i - T_s)/(T_t - T_s)$$

where T_i is the temperature indicated by the measuring junction and T_t and T_s are the total and static temperatures, respectively, of the gas. The apparatus, technique and method of analysis of the test data are described in the AF Technical Report No. 6455 referred to earlier. The orientation of the test thermocouple with respect to the gas flow was that previously designated as Position No. 1 - the sensing element directly upstream from the support. The experimental values of $T_t - T_i$ versus velocity are shown in figure 2A. Calculated values of recovery factor versus velocity and Mach number are shown in figure 2B.

DISCUSSION OF RESULTS

No measurements were made of the mechanical strength of the tubular thermocouples. It is recognized that the present units were designed primarily for expermental studies of basic performance characteristics of this type of construction. In the design of probes of this type for jet engine applications, due consideration must be given to the problem of mechanical stability. In the present units the longitudinal seam along the tubular thermoelement is open. It is believed that welding this seam would greatly increase the mechanical stability of the unit without materially affecting the performance characteristics.

The response rate of the present tubular thermocouples corresponds approximately to that of a No. 24 gage bare wire Chromel-Alumel thermocouple exposed directly to an exhaust gas stream.

The value, .63, for the recovery factor of the tubular thermocouple is somewhat greater than that observed for a butt-welded junction transverse to a gas stream. It is believed that this may be due to the location of sensing junction only one diameter upstream from the supporting member.

Table 1

Summary of Response Tests of Tubular Chromel-Alumel Thermocouples

	Characteristic Time - Seconds, at Flow Rates in lb/sec ft^2								
	(Position No. 1)			(Position No. 2)			(Position No. 3)		
	2	4	6	2	4	6	2	4	6
				Unit No. 1					
	1.00	0.70	0.58	1.05	0.75	0.65	1.15	0.90	0.80
	1.00	0.72	0.60	1.10	0.70	0.70	1.15	0.95	0.80
	1.15	0.80	0.60	1.05	0.77	0.70	1.10	0.90	0.80
			0.65		0.75	0.65			
Mean	1.05	0.74	0.61	1.07	0.74	0.67	1.13	0.92	0.80
				Unit No. 2					
	0.98	0.75	0.62	0.94	0.70	0.57	1.14	0.84	0.70
	1.08	0.70	0.58	0.94	0.71	0.63	1.18	0.94	0.70
	0.92	0.88	0.62	1.01	0.70	0.64	1.20	0.82	0.70
Mean	1.00	0.78	0.61	0.96	0.70	0.61	1.17	0.87	0.70

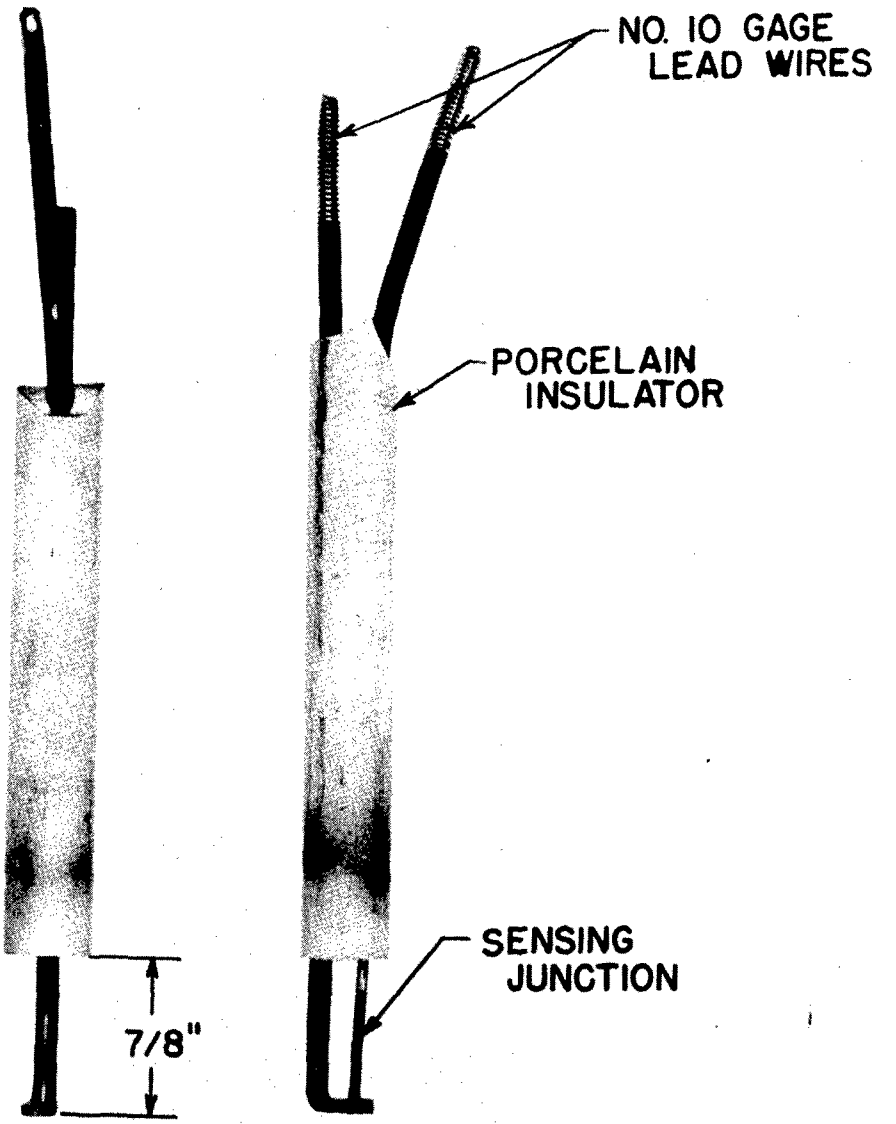
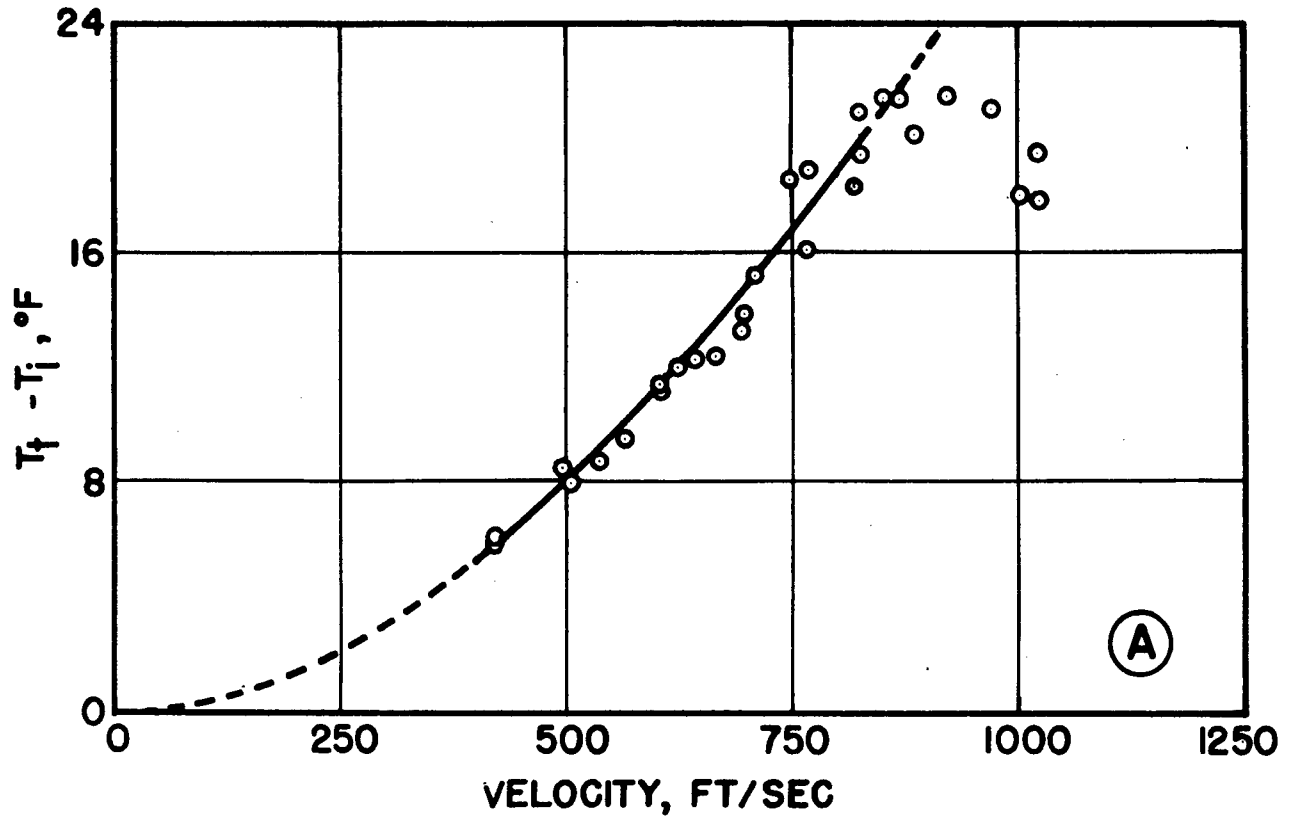


FIGURE 1 TUBULAR CHROMEL - ALUMEL THERMOCOUPLE



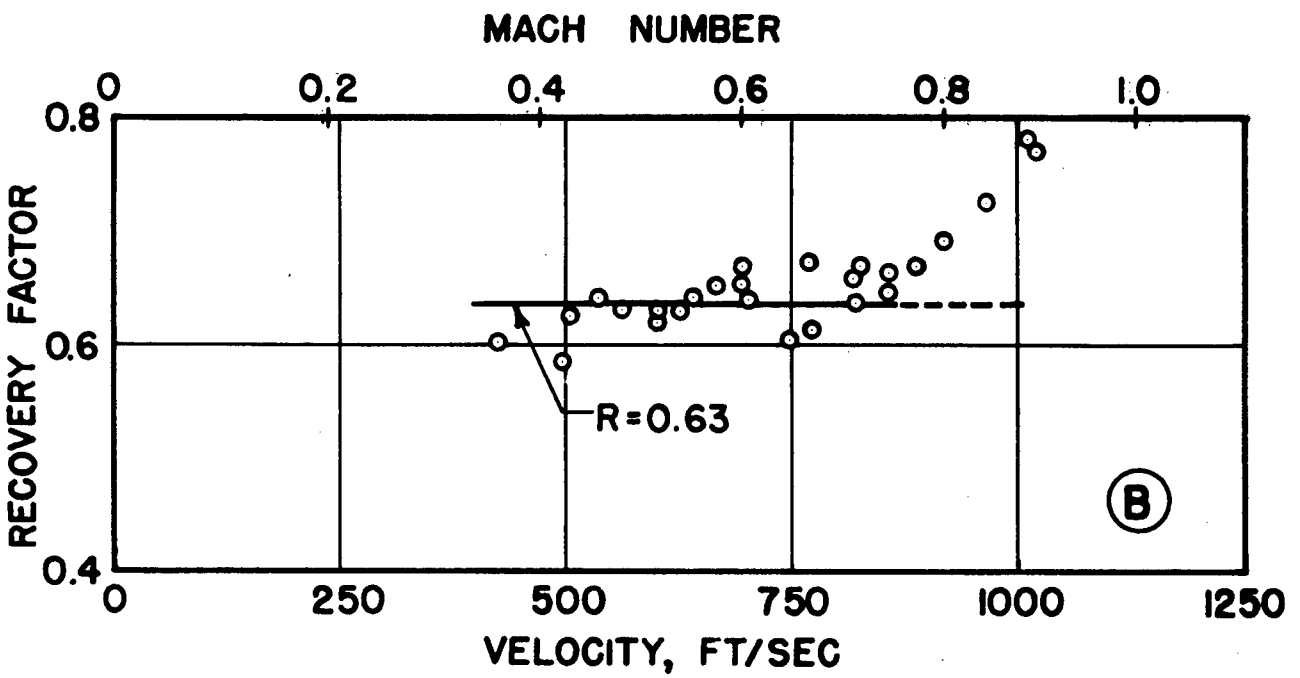


FIGURE 2 RESULTS OF RECOVERY FACTOR TEST